Jour. Agric. Res. China (中華農業研究) 34 (4) : 369~390 (1985)

Breeding for Disease and Insect Resistances in Keng Rice[1]

Chen-seng Huang[2]

Abstract: Tainung 67 was crossed with Tetep, Carreon, Dawn and other donor parents followed by 3 to 4 consecutive backcrossings to Tainung 67 for improving its blast resistance. A genetic study on the BC_1F_1's revealed that Tetep was most numerous in the genes resistant to 4 races of the blast fungus tested. An upland blast nursery with corn border lines facilitated the screen-testing of breeding lines. Many new selections from this breeding program were resistant to the blast disease and outyielded Tainung 67. Tainung 67 was also crossed with yellow dwarf resistant Firooz, followed by 2 consecutive backcrossings to Tainung 67. From the segregating progenies of these backcross hybrids, 11 new strains resistant to yellow dwarf were selected. The yields of 2 strains surpassed that of Tainung 67. The brown planthopper resistance of a *Oryza rufipogon* was transferred to Ponlai by 2 consecutive breeding programs. TNGY8849, a final selection that was resistant to blast and brown planthoppers, is being recommended for registration. Various other varieties possessing *Bph 1*, *bph 2*, *Bph 3* and *bph 4* were also crossed with Tainung 67, followed by 2 consecutive backcrossings. The resistant strains selected from the segregating materials of these hybrids are being tested in the preliminary yield trial. Several *japonica* cultivars showed resistance in a test for white-backed planthopper resistance, including moderately resistant Tainung 67. A breeding program and the genetic study related with the resistance are in progress. Twenty-one double cross F_1's between the lines selected mostly from the above mentioned backcross breeding programs were subjected to anther culture cooperated with tissue culturists. A total of 1,567 green AC_1 plants derived from the anther culture gave only 230 diploid AC_1S_1 lines for screen-testing. The rate of this diploid recovery was greatly improved later. Segregation patterns of blast, planthopper resistances and shattering habit of rice grains among the AC_1S_1 lines showed that the combination of different desirable traits by double crossing followed by anther culture will be successful and readily useful.

Introduction

Rice surplus, a headache problem in recent years, in Taiwan has been so far encouraged by rice prices of official purchase, successful rice improvement work and a

1 Contribution No. 1239 from Taiwan Agricultural Research Institute, under the financial support of the Council for Agricultural Planning and Development, project number Nung-chien 73-4.1-tsan-35.

2 Senior specialist, Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan Republic of China.

dropping of the per capita consumption of rice. The result is that our government has to put this rice into export at prices of around $200 a ton or slightly more, that eventually cost the government about $650 a ton (1). Inevitably a large amount of deficit accumulates by this official purchase and sale. Moreover the export dumping provokes the U. S. to claim for a necessity to limit our rice export (2). One of the remedies for solving this problem will be to reduce the rice area and to cut down the cost of rice production. Our government is now making efforts in converting rice field to dryland cropping and to reduce rice by the PIK policy. For reducing furher the cost of rice production, a sharp expansion in the size of rice farming and a simplification of mechanized rice culture are needed. Our farmers spend about NT$1,000 million a year to buy the chemicals for controlling the blast disease and planthoppers (24). Needless to say, the use of resistant varieties is the most economical means for their controls. It not only reduces the cost of rice prodution but also control diseases and insects without any adverse side-effect resulting from the application of agricultural chemicals. The results of our efforts on this lines of work are reported below.

Materials and Methods

Breeding for blast (BL) disease resistance

Tetep, Dawn, Carreon and Dular were used as the sources of BL resistance in a backcross breeding program, for which Tainung 67 served as the recurrent parent. We repeated the backcrossing 3 to 4 times. The BC_1F_1's of these cross combinations were tested for the resistance against four races of the blast fungus, ID-14, IE-2, IF-3 and IG-2 that attacked Tainung 67 for a genetic study and selection. In the following BC generations, we alternatively used the Kuoshin BL nursery and the artificial inoculation of the composity blast fungus for testing the resistance. Other sources of BL resistance were also used such as Fujihikari, Toyonishiki, Sensho, Pi-lines, BL-lines, Tainung 62 and Tainan 6 that belonged to *japonica*, and IR34 to IR50, various IR-lines, Taichung sen 3, 10, Tainung sen 12, Seweon 290, M1-48, Ta-poo-chu-z and Chu-z belonging to *indica*. We crossed these varieties with Tainung 67, and the F_1's were backcrossed to Tainung 67 once without any further backcrossing. The ordinary pedigree method was followed in propagating and selecting these hybrid materials. An upland blast nursery with corn border lines was established about one month after the transplanting of both rice crops for testing breeding lines mostly of later segregating generations. We also sent a number of advanced lines to the Chiayi AES/TARI and the IRRI, Philippines for BL test, so that the lines resistant to a broader range of pathogen could be selected. From each of the advanced line that showed a certain degree of uniformity, mostly at the BC_1F_4 or BC_3F_3 or BC_4F_3 or later generations, we selected 3 to 5 individuals per line and bulked their seeds to establish a strain for yield testing. The ordinary replicated field plots were employed in the yield test.

Breeding for resittance to yellow dwarf and other diseases

Cultivar Firooz provided the source of yellow dwarf resistance to be introduced into Tainung 67 by backcross breeding. The F_1 between Tainung 67 and Firooz was back-

crossed to Tainung 67 two times. The segregating materials of BC generations were inoculated with *Nephotettix* leaf hoppers carrying the pathogen for discarding yellow dwarf susceptible plants. We used the pedigree method after the BC_2F_1, and 11 strains were finally selected for yield trials.

For selecting the lines resistant to the bacterial leaf blight disease, we generally inoculated our breeding materials by clipping method with the Academia Sinica's isolate No. 604 of the bacterium. The sources of resistance used were TKM-6, DV85, various IR lines, Wase-aikoku, Tainan 6, Koshihikari and other *japonica* varieties.

Breeding for planthopper resistance

The F_1 between a Tainung 61 semidwarf mutant and a wild rice, *Oryza rufipogon* (IRRI Acc. No. 100923) was backcrossed to the mutant 2 or 3 times to transfer the brown planthopper (BPH) resistance. We selected the BPH resistant lines from these hybrid materials, and crossed them with 2 BL resistant *japonica* cultivars. After a series of propagation and selection on these hybrid materials, various strains resistant to BL and BPH were established, and 7 strains of them reached the final selection after the yield trials in the replicated field plots. They were thus entered in the regional yield tests at 7 sites in the island for one year. They also received the BL test at several BL nurseries including those at Chiayi AES and IRRI, Philippines for about 3 years.

The BPH resistance sources in cultivated rice were also used as the donor parents, they were Chianung yuh 243 and other varieties that possessed *Bph 1*, Tainung sen 12 and others having *bph 2*, Rathu Heenathi and others possessing *Bph 3* and Babawee of *bph 4*. We backcrossed the F_1's between Tainung 67 and these donor varieties to Tainung 67 two times and selected their progenies for BPH resistance according to the pedigree method.

For the white-backed planthopper (WBPH) resistance, we tested first of all a number of *japonica* cultivars with seedbox technique to identify the *japonica* resistance sources. Then crosses were made between the resistant cultivars with other varieties for breeding purposes and a genetic study.

Application of anther culture to varietal improvement of japonica rice

The F_1's of 21 *japonica* crosses, mostly the double crosses between lines selected from backcross breeding, were used as the materials for anther culture. At seedling stages, we subjected these F_1's to a blast test to eliminate the blast susceptible plants. The tissue culture laboratory, TARI undertook anther culture of the remaining resistant F_1 plants, when their young panicles reached the meiosis stage. "AC_1" denotes hereafter the plants from the first time of anther culture and "AC_1S_1" their progenies from the first selfing.

The AC_1 seedlings produced by the tissue culture laboratory were transferred to the breeder for the subsequent growth and selection. We selected only the diploid plants and discarded the haploid, tetraploid and other undesirable plants. Several seed samples were taken from each of the selected AC_1 diploid plants to provide the seed for testing the BL, BPH and WBPH resistances and agronomic performances of their progenies or

AC_1S_1's. A progeny consisted of 60 plants that were individually spaced. At harvest, we bulked seed of 5 to 6 plants from each of the selected lines that showed an acceptable degree of uniformity to establish a strain for replicated yield trials.

Results and Discussion

1. Breeding for blast disease resistance

In the past

Since the beginning of commercial cultivation of Ponlai rice in Taiwan, the blast disease has been a serious problem (4). In the past 30 years, efforts were made to breed blast resistant varieties by our breeding stations, supported by several sophisticated research projects such as irradiation experiment (4), development of multiline varieties resistant to different races of the fungus (13, 15) and genic analyses of the resistance against different races of the pathogen (17). A large number of resistant varieties were developed during this period, such as Kwan-fu 1 and 401, Chianung 242, Taichung 181, 186, Kaohsiung 137, 138, 141, and highly resistant Tainan 6 and Tainung 62. Most of these varieties did not received much popularity from farmers, or their resistances did not last long. More than 90% of the blast resistant varieties that were registered received the source of resistance from a single variety, Litchi-hung, which is known to possess the resistance gene of *Pi-k* alleles (11). A narrow range of resistance germplasm used, inadequate testing technique for the resistance and the rare use of

Table 1. Occurrence of leaf (LBL) and panicle (PBL) blasts in Tainung 67 and Tainan 5 (in parenthesis) at five disease nurseries.

Type	Year	Chuanwei	Chushan	Chiayi	Wanluan	Kuanshan	Ave.	Upland nursery
LBL	1976	3(4)*a*	4(4)	5(5)	3(4)	5(5)	4(4)	5(5)
	1979	8.7(6.8)	7.9(5.4)	8.8(7.3)	7.5(6.5)	8.0(7.8)	8.2(6.8)	9.0(8.0)
	1980	9.0(9.0)	9.0(8.1)	7.5(5.0)	6.6(8.2)	9.0(8.9)	8.2(7.8)	9.0(9.0)
	1981	9.0(9.0)	8.3(7.8)	8.0(6.0)	6.0(4.6)	8.5(5.1)	8.0(6.5)	9.0(9.0)
	1982			8.0(5.5)		8.0(8.0)	8.0(6.8)	9.0(9.0)
	1983			8.5(7.0)		8.0(5.5)	8.3(6.3)	8.5(7.5)
	Ave.	7.4(7.2)	7.3(6.3)	7.6(6.0)	5.8(5.8)	7.8(6.7)	7.4(6.4)	8.3(7.9)
PBL	1976	1(2)	1(1)	D(5)	2(4)	D(D)	1(3)	
	1979	D*b*-(5)	9(9)	D(7)	9(9)	D(7)	9(7)	
	1980	—(—)	—(—)	7(5)	9(9)	—(—)	7(7)	
	1981	9(9)	9(7)	7(9)	7(7)	7(3)	9(7)	
	1982			6.0(8.0)		1.0(—)	3.5(8)	
	1983			8.0(7.0)		4.0(3.0)	6(5)	

a; 0=HR, 1=R, 3=MR, 5=MS, 7=S, 9=HS. b, D=Dead due to LBL.

backcross breeding method were the probable causes leading to the above consequence, although the breakdown of resistance due to the change of pathogenic races could not be neglected.

Table 2. Reaction of rice variety Tainung 67 to different races of the blast fungus (Institute of Botany, Academia Sinica).

Race	Reaction of Tainung 67
I C - 18	R
I C - 26	R
I D - 14	S
I E - 2	S
I F - 3	S
I F - 4	R
I G - 2	S
I H - 1	R
I I - 1	R

In the meantime, Tainung 67 that was supposed to receive the semidwarf plant type from Taichung Native 1 and released in 1978, showed a breakthrough in the ceiling yield potential and other desirable traits (14). Its cultivated area expanded with an unprecedented manner, reaching more than 70% of the total rice area of Taiwan in 1982 (3). This variety is slightly more susceptible to the blast disease when compared with Tainan 5, the most leading variety before Tainung 67. This is shown by the results obtained in the 6-year uniform blast nurseries (Table 1). The blast disease occurred in Tainung 67 has been so far controlled by fungicides that cost farmers in Taiwan about NT$300 million a year (1981) (34). Therefore, it is most urgent to introduce blast resistance into Tainung 67, which is known to be susceptible to 4 among 10 races of the fungus tested (Table 2). Among these 4 races, IG-2 has been one of the two races that were found most common in the island in recent years. Another commonest race is II-1, to which Tainung 67 is resistant. II-1 together with IG-2 accounted for 90% of the total isolates collected in the island during 1974-1977 (27).

Backcross breeding to Tainung 67

A backcross breeding program was initiated in the 1979 second rice season to introduce the blast resistances of Tetep, Carreon, Dawn, Dular, Sensho, TKM-6, and M_1-48, into Tainung 67. No further backcrossing was made for the crosses related with Sensho, TKM-6 and M_1-48 after the BC_1.

In the 1980 second crop, the BC_1 plants of Tainung 67^2/Dawn, Carreon, Tetep crosses were inoculated with four races of the blast fungus, ID-14, IE-2, IF-3, and IG-2, that attacked Tainung 67. The Institute of Botony, Academia Sinica prepared the spore suspensions for this test. We made 4 wounds on each of three leaves per BC_1 plant by rubbing with a used ball-pen tube and spot-inoculated on them with the four races of the fungus. The inoculated leaves were covered with a plastic bag. Any plant that produced the conspicuous lesion on one or more of the three leaves is considered susceptible. We completed this test before the flowering of the plants and selected the plants resistant to all four races for the second backcrossing.

The segregations of leaf blast resistance in the above test in the BC_1F_1's of Tainung 67^2/Dawn, Carreon, Tetep crosses are shown in Table 3. Based on the patterns of

segregation, it is concluded that the resistance of Dawn to races ID-14 and IG-2 seems to be controlled by a single dominant gene, to race IE-2 by 3-4 pairs and to race IF-3 by 2-3 pairs of genes. The resistance of Carreon against races ID-14 and IG-2 seems to be controlled by a single dominant gene and to IE-2 and IF-3 by 3-4 pairs of genes. It seems that more resistance genes were involved in the Tetep cross; for example to races ID-14 and IG-2, the Tetep's resistance seems to be controlled by two pairs of genes and to races IE-2 and IF-3, 4-6 pairs of genes seem to be involved (Table 3). Therefore, We laid more emphasis on the hybrid materials related with Tetep in the following backcrossings.

Table 3. Segregation of leaf blast resistance in the BC_1F_1's of TNG67²/Dawn, Carreon, Tetep to 4 races of the blast fungus (1980 2nd crop).

Combination	Race	R	S	Possible ratio $p(X^2)>5\%$	Possible Gene pairs
TNG67²/Dawn	I D—14	13	18	1 : 1	1
	I E— 2	28	3	7 : 1, 15 : 1	3, 4
	I F— 3	25	6	3 : 1, 7 : 1	2, 3
	I G— 2	13	18	1 : 1	1
TNG67²/Carreon	I D—14	21	34	1 : 1	1
	I E— 2	49	6	7 : 1, 15 : 1	3, 4
	I F— 3	49	6	7 : 1, 15 : 1	3, 4
	I G— 2	21	34	1 : 1	1
TNG67²/Tetep	I D—14	28	12	3 : 1	2
	I E— 2	38	2	15 : 1, 31 : 1, 63 : 1	4, 5, 6
	I F— 3	39	1	15 : 1, 31 : 1, 63 : 1	4, 5, 6
	I G— 2	29	11	3 : 1	2

The BC_2F_1 families of Tainung 67³/Dawn, Carreon, Tetep crosses were grown in the 1981 first crop at Kuohsin nursery located in a valley of Nantou prefecture, where serious blast occurs every year. The segregation patterns of the blast resistance varied greatly from family to family. Continuous segregation of the resistance appeared most frequent in the Tainung 67³/Tetep cross, although discontinuous segregation occurred in all three crosses tested. The resistant BC_2F_1 plants that exhibited a plant type close to Tainung 67 were replanted in a pot and taken back to the institute for the third backcrossing.

We grew a half of the seedlings of each BC_3F_1 family in a seedling box and artificially inoculated them with the spore suspension of the composite blast fungus in the 1981 second crop season. Another half of the seedlings were planted in an ordinary breeding nursery without any artificial inoculation. The results of leaf blast test on the

Table 4. Segregation of LBL resistance in the BC_3F_1 and BC_4F_1 of different rice crosses.

BC_3F_1 Cross	R>S	R=S[a]	R<S	Total families	BC_4F_1 Cross	R>S	R=S[a]	R<S	Continuous segregation	Total families
TNG67[4]/Dawn		2	3	5	TNG67[5]/Dawn		4	2		6
TNG67[4]/Carreon	1			1	TNG67[5]/Carreon		2			2
TNG67[4]/Tetep		16	7	23	TNG67[5]/Tetep	3	48	3	4	58
TNG67[3]/Dular		8		8	TNG67[4]/Dular	3	15	1	2	21
Total familes	1	26	10	37	Total	6	69	6	6	87
Source of inoculum	Inoculated with the fungus from various locations				Source of inoculum	At Kuohsin BL nursery				
Year and season	1981 2nd crop				Year and season	1982 1st crop				

a: Based on 1 : 1 x^2-test.

BC_3F_1's are shown in Table 4. The number of one-to-one segregating families tended to increase when one more time of backcrossing was added. Artificial selection was practiced during the heading stage of inoculated BC_3F_1's to pick up the resistant plants having a plant type resemble to Tainung 67. They were thus backcrossed to Tainung 67 the fouth time.

In the 1982 first crop, we tested three groups of materials at the Kuohsin nursery. They were the BC_4F_1's, the BC_3F_2's screened after BL test and without BL test at the BC_3F_1's as mentioned above. The results obtained from the BC_4F_1's are shown in Table 4. Among 87 BC_4F_1 families, 79.3% segregated the resistant and susceptible plants in a ratio of 1:1. In the BC_3F_2 populations, of which BC_3F_1's were disease-tested and screened, 90.2 % were found to segregate a half or more number of resistant plants in a population, while only 50.0% of those BC_3F_2 populations without blast-test at the BC_3F_1 segregated such resistant plants. A large number of blast resistant plants having a

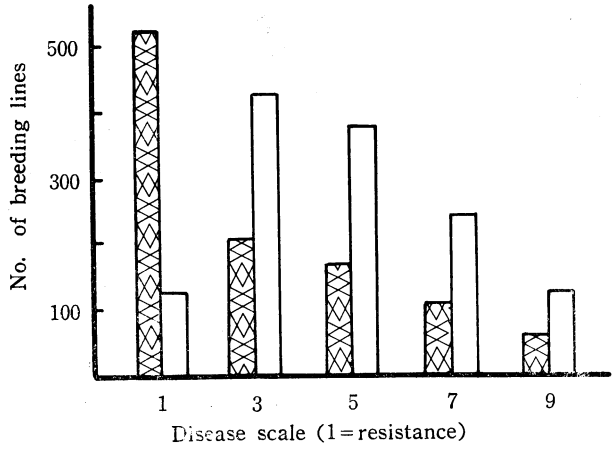

Fig. 1. Comparison of the BL resistance between 1983-II (shaded) and 1983-I crop breeding lines at upland disease nursery with corn border lines.

plant-type resemble to Tainung 67 were selected from the BC_4F_1's and BC_3F_2's at Kuo-shin nursery for continuous propagation and screening.

Use of other sources of blast resistance

For using a wide range of blast resistance germplasm, we also crossed Tainung 67 with two groups of rice varieteis. The first group was the blast resistant *japonica* varieties, including Fujihikari, Mutsunishiki, Toyonishiki, Sensho and those Pi-lines and BL-lines developed by Japanese, Tainung 62 and Tainan 6, etc. This group of rice generally has a better rice quality and the blast resistance mostly from their *indica* ancestors. The second group included various IR strains from IR34 to IR50 and to IR 21916 or IR21931 etc., and other *indicas* like Tainung Sen 12, Taichung Sen 3, 10, Suweon 290, M_1-48, Ta-poo-chu-z and Chu-z etc.

The F_1 hybrids from the above crosses were backcrossed to Tainung 67. The pedigree method was followed without further backcrossing in the following generations to propagate and select the segregating materials. The bulk method using rice transplantor was also employed for the advancement of generations. We conducted the blast test at later segregating generations of these materials, when the upland blast nursery with corn border lines was available. Generally speaking, the plant types and rice quality of these segregating hybrids were poor when compared with those received more backcrossings. Therefore, only 30 lines of *japonica* source and 43 lines of *indica* source reached the preliminary yield trial.

Upland blast nursery with corn borderlines

For screening a large number of breeding lines for blast resistance it is necessary to have a stable but severe disease nursery every rice season. The disease occurs most at 21°-22°C minimum day temperatures and a dew period of 6 or more hours per day (25). We produced this environment by setting the disease nursery in April-May (1st crop) and September-October (2nd crop) and covering the plant seedlings with a plastic sheet at night protected with corn borderlines. As for other nursery managements, such as fertilizer application, irrigation, inoculation etc, we followed the methods used in the ordinary blast nursery. The results were very successful, even in the second rice season severe blast disease occurred without exception.

We started to test our breeding lines in this blast nursery in the 1982 second rice season. The blast resistances of the 1983-I and 1983-II breeding lines were compared in Fig. I. The resistant lines in the 1983 second crop increased drastically after the selection based on the results of blast test conducted in the 1983 first crop.

Yield trial of blast resistant new strains

Since the BC_3F_3 lines from the backcross breeding and the BC_1F_4 or BC_1F_5 lines from other crosses reached an acceptable uniformity for agronomic traits in the 1982 second crop, we bulked seed of the individuals within lines to establish strains for a preliminary yield trial. A total of 165 strains including those blast resistant were tested in the replicated yield trial in the 1983 first crop. In the following season, 56 strains of them got into the advanced yield trial, and a new set of 126 strains were tested in replicated plots for the preliminary yield trial. The number of entries and their donor parents of

resistance are shown in Table 10 with those strains resistant to insects. The agronomic performaces of some BL resistant elites are shown in Table 5. Many of these entries gave a grain yield similar to or higher than Tainung 67 and were resistant to blast disease, although we do'nt know how many resistance genes were involved in different strains, or how long the resistance will last. We recommended TNGY 148 to be participated in the regional yield test of Ponlal rice starting from the 1984 first crop.

Table 5. Examples of new blast resistant strains of rice having different sources of resistance.

TNGY NO.	Cross	1st crop			2nd crop			LBL	PBL
		Yield (kg/ha) (%)	DFTH-a	Pl. hgt. (cm)	Yield (kg/ha) (%)	DFTH-*a*	Pl. hgt. (cm)		
99	TNG67⁴/Tetep	8,333(105)	93	107	4,573(91)	65	110	1(R)	R
101	TNG67⁴/Tetep	8,500(107)	93	110	4,563(91)	67	108	3(MR)	MR
148	TNG67²/Fujihikari	8,296(104)	84	112	6,727(134)	57	111	1(R)	R
667	TNG67⁴/Dawn	8,630(108)	92	112	5,464(109)	62	117	2(R)	R
678	TNG6⁴/7Tetep	8,407(106)	91	106	5,098(101)	61	108	3(MR)	MR
696	TNG67⁴/Dawn	7,981(100)	92	114	5,332(106)	61	115	2(R)	R
711	TNG67⁴/Carreon	8,222(103)	93	114	6,245(124)	64	119	3(R)	MR
726	TNG67⁴/Tetep	8,130(102)	93	109	5,348(106)	64	114	1(R)	R
CK	TNG67	7,963(100)	92	106	5,029(100)	63	115	S	S

a: Days from transplanting to heading.

From our efforts shown above, more *japonica* strains and lines having the BL resistance from *indica* varieties will come up for yield trials. Introduction of blast resistance genes into *japonica* varieties has also been the approach of Japanese researchers in this line in recent years. Gene *Pi-k* from Litchi-hung to Kanto 51, another *Pi-k* to Kusabue, *Pi-ta* from Tadukan, *Pi-z* from Zenith, *Pi-z*^{t} from TKM-1 and *Pi-b* from Tjina etc. to japanese varieties (28), all are the examples. Many of these newly bred resistance varieties of *japonica* have been also used in our breeding program. In some case, they eventually introduced the same resistance gene from different donor parents (28). Our principle approach is to introduce the resistance gene from *indica* into Tainung 67 and to accumulate them. We may waste our efforts in introducing the same gene from different donors in some cases, however, we should be able to introduce different resistance genes from *indica* varieties into *japonica* as japanese did.

2. Breeding for resistances to yellow dwarf and other diseases

In the past

Yellow dwarf disease, although not a major disease of rice in Taiwan, occurs in the second crop with the increasing importance (7, 22). The disease damage is particularly serious in the ratoon cultured rice, which is considered one of the approaches to further reduce the cost of production in rice. Yellow dwarf disease, incited by a mycoplasma, can be easily controlled by the application of insecticides at seedling stages of

the second crop rice, since it is transmitted by the vector insects, *Nephotetix* leafhoppers. Of course, use of the resistance is the cheapest method of disease control without any adverse side-effects resulting from the application of agricultural chemicals.

Chen *et al.* (7) detected three varieties, namely Firooz, Kabara and C4-63 to be highly resistant to yellow dwarf disease among greenhouse and field-tested 1,430 rice varieties. The resistance was later found to be controlled by a single dominant gene (21). A backcross breeding program to introduce the resistance gene of Firooz and Kabara into Tainan 5 and Tainung 61 (22) resulted in the development of five yellow dwarf resistant strains of Tainung 61 genetic background, YD-15, 22, 28, 62 and 75, four being of Kabara and one being of Firooz origins (22) of the resistance. These YD strains were not released due to the rapid expansion of the rice area of high yielding Tainung 67.

Backcross breeding to Tainung 67

In the 1979 second crop, another backcross breeding program was initiated by us to introduce the yellow-dwarf resistance into Tainung 67. The outline followed in this breeding program is shown below.

1979-II……Tainung 67/Firooz, crossed.

1980-I……F_1, Tainung 67/Firooz, backcrossed to Tainung 67.

1980-II……BC_1F_1, Tainung 67^2/Firooz, 2 families, inoculated with the vector insect carried the pathogen by pathologist Dr. C. C. Chen, then screened and backcrossed again by us.

1981-I, II…BC_2F_1, Tainung 67^3/Firooz, 12 families, inoculated and screened as in the BC_1F_1.

1982-I……BC_2F_2, 38 populations, screened in the field.

1982-II……BC_2F_3, 22 lines, screened in the field.

1983-1……11 strains in the preliminary yield trial (PYT).

Table 6. Agronomic performance of yellow-dwarf resistant strains (TNG67³/Firooz) in replicated yield trials (1983).

Strain No.	1st crop				2nd crop				Lodging index, 2nd crop	LBL	BLB
	DFTH[a]	Pl. hgt. (cm)	Yield kg/ha	Yield (%)	DFTH[a]	Pl. hgt. (cm)	Yield kg/ha	Yield (%)			
TNGY 3	93	113	6,815	(86)					—	4—5	—
TNGY 13	89	116	7,075	(89)					—	4—6	—
TNGY 18	89	108	7,704	(97)	.....	Discard			—	4	—
TNGY 19	93	109	7,870	(99)					—	3—4	—
TNGY 20	92	110	8,241	(104)	65	107	5,484	(109)	0.5	3—4	3—5
TNGY 22	91	110	8,389	(105)	64	111	5,727	(114)	0	3—4	3—5
Tainung 67 (CK)	92	106	7,963	(100)	62	115	5,029	(100)	1.25	7—9	3—5

a: Days from transplanting to heading.

1983-II……2 strains in the advanced yield trial, another 2 strains in the PYT.

1984……Thirteen TNGY strains from this breeding program will be tested for the disease resistance and yield performance.

The agronomic performances of six TNGY strains tested in replicated yield trials in 1983 are shown in Table 6. There were 2 strains, TNGY 20 and 22 outyielded Tainung 67 (Table 6). We will continue the test of these strains for grain yield and the disease resistance and cross them with the insect resistant lines.

Resistance to the bacterial leaf blight (BLB)

To the leaf blight disease Tainung 67 was commonly rated as moderately susceptible in the uniform disease nursery, while Tainan 5 was resistant. Local extension workers reported the sporadical occurrence of the disease in the second crop of Tainung 67 in recent years, although no increasing trend of the diseased area of rice has been noted. Therefore, the disease is still considered minor in Taiwan. Since no economical chemical is available for controlling this disease, we have to introduce the resistance into Tainung 67.

Four pathotypes of the leaf blight bacterium in Taiwan were identified based on five Japanese differentials (20). Tainung 67 responded to these four pathotypes in a score range of 5-7. Even though isolate No. 607 belonging to pathotypes III gave a higher disease score"7" than No. 604 belonging to pathotype II did in greenhouse (20), we found a considerably stronger pathogenicity of isolate No. 604 in the field test. Therefore, we have been using isolate No. 604 in testing our breeding materials every season for the disease resistance.

Two groups of resistance sources were used in the crossing, one was the *japonica* varieties such as Wase-aikoku, Tainan 6, Koshihikari and other japanese varieties, and another was the *indica* like TKM-6, DV85 and various IR strains. The segregating materials of various generations were inoculated by clipping method with the bacterium suspension of Academia Sinica isolate No. 604 prepared by us. The results of BLB test on yield-tested strains in the 1983 second crop are shown below.

Disease scale	2	3	4	5	6	7	8	Total strains
Advanced strains		1		36		19		56
Preliminary strains		12		85		28		127

3. Breeding for planthopper resistance

In the past

The brown planthopper (BPH) and white-backed planthopper (WBPH) have been the most destructive insects of the second crop rice in Taiwan. The total rice area infected with the insects in the island has been about 80,000-120.000 ha annually and the rice area applied with insecticides for BPH control being about 150,000-250,000 ha per year. The insects, so far, have been controlled by the chemicals that cost farmers about NT$800 million a year (1981) (24). Studies and breeding for the resistance to

brown planthoppers in the past centered mostly on *indica* varieties, of which rice quality did not meet the consumer's requirement (12). For this reason, no BPH resistant *indica* varieties that were released in the past became a major variety in Taiwan. Tainung 68 released in 1982 was the first BPH-resistant *japonica* cultivar in Taiwan. Its resistance is expressed at late growing stages (5), although no BPH resistance gene was detected by seed-box technique. Other new *japonica* strains resistant to BPH were Chianung yuh 243 that received the resistance of Mudgo, and Tainung yuh 8005 and 8849 from a wild rice, *Oryza rufipogon* (16). Although without BPH resistance gene, Tainung 67 showed a better tolerance to BPH than Tainan 5 at late growing stages of the second crop rice. This led to the reductions in the BPH infected area by 21% and in the controlled area by 23 % in the island second crops of 1977 to 1981.

Table 7. Yield performance of two BPH-resistant strains of rice in three years.

Year-season	TNGY8005	TNGY8849	Tainung 67	Site
1981—I	6,700(94)	6,800(95)	7,150(100)	TARI,
—II	5,040(122)	4,940(119)	4,140(100)	replicated plots
1982—I	5,920(100)	5,700(96)	5,951(100)	Regional tests,
—II	5,320(98)	5,050(93)	5,450(100)	7 sites
1983—I	6,960(100)	6,770(96)	6,960(100)	TARI,
—II	5,997(104)	6,240(108)	5,760(100)	large, plot
Adv.-II[a]	5,980(119)	6,170(123)	5,030(100)	Replicated plots

a: Advanced yield test.

Table 8. Reaction of BPH-resistant rice strains to different BPH biotypes with seedbox technique.

Strain No.	Reaction to biotype			BPH damage 3/		White-backed planthopper
	1 1/	2 2/	3 2/	Degree 4/	Pattern 5/	
TNGY 8005	R	R	R	2.5	I	S
TNGY 8849	R	MR	R	3.0	II	R
TNG 67	S	S	S	—	—	MR

1/ ··Tested at the F_3 line, 2/ at the F_4 line.
3/ : Tested at the F_6 strain with biotype 1.
4/ : Average of damage scales in the damage progress curve.
5/ : Pattern of the progress curve; I, II=lower degrees of damages than H105 with different slopes of the curves.

BPH-resistance from a wild rice *Oryza rufipogon*

In the progenies of the F_1 between Tainung 61 semidwarf mutant and *O. rufipogon* (IRRI Acc. No. 100923) backcrossed with the mutant two or three times, BPH-resistant

Table 9. Reaction of BPH-resistant rice strains to leaf blast disease.

Year-season	TNGY 8005	TNGY 8849	Tainung 67	Site
1981—I	1.5	3	8.3	4 nurseries
—II	1	1.5	9	TARI, Chiayi
1982—II	3	2	9	TARI, Chiayi, IRRI
1983—I	1.5	1.5	9	TARI, Chiayi
—II	1.8	2.2	9(1:IRRI)	TARI, Chiayi, IRRI

lines were detected with seedbox technique (16). Tainung 61 that belongs to *japonica* is the two dose parent of Tainung 67. From the progenies of the F_1's between these BPH resistant lines and two blast resistant *japonica* strains, we selected and established new rices trains resistant to BPH and BL in the 1980 second crop (Table 8, 9). The BPH resistance gene was found to be *Bph 3* or certain unidentified gene(Table 8). The selected strains were yield-tested from 1981 continuously for three years including regional tests at 7 sites in 1982 (Table 7). TNGY 8005 yielded almost similar with Tainung 67, While TNGY8849 yielded higher than Tainung 67 by 8% to 23% (Table 7). Both TNGY8005 and 8849 were resistant to blast disease, not only in Taichung and Chiayi nurseries but also at IRRI, Philippines. The range of BL resistance is considered wide. Although TNGY8005 showed a yield potential similar to Tainung 67, it was not resistant to the white-backed planthopper (Table 8) and had the poor eating quality of rice. Therefore, we will recommend TNGY8849 for registration in 1984.

BPH resistance from cultivated rice varieties

Four BPH resistance genes have been known so far in the cultivated rice. The typical varieties for these genes are Mudgo for *Bph 1*, H105 for *bph 2*, Rathu Heenathi for *Bph 3* and Babawee for *bph 4* (26). These genes, particularly *Bph 1* and *bph 2*, have been incorporated into various IR strains, that can also be used as the source of resistance. We started to introduce these genes into Tainung 67 in 1978. TKM-6, Chianung yuh 243, IR28 and other IR varieties and strains provided the *Bph 1* gene for our breeding program. Taiunug sen 12 and Taichung sen 10 provided the *bph 2* gene, TNGY 8005, 8849 and Rathu Heenathi the *Bph 3* and Babawee the *bph 4*.

The F_1's between Tainung 67 and the resistant stocks mentioned above were backcrossed to Tainung 67. The resulted BC_1F_1's were tested by Plant Protection Department, Chiayi AES/TARI for BPH-resistance and then screened by us. In some crosses the backcrossing and screening were repeated one more time. Seedbox technique was used for testing and screening the segregating materials. In the second crop when the insect prevailed, we also used the severe occurrence of BPH in the field for screening the materials. The strains selected and established from these materials reached yield-test in 1983(Table 10). In the 1984 first crop, more new strains resistant to BPH will be entered in the preliminary yield trial. Apparently, the times of backbrossing made in this breeding program were not adequate. Therefore, the rice quality, plant

type and other agronomical traits of these strains need further improvement.

Table 10. Number of rice strains and their donor parents tested in the preliminary and advanced yield trials in the 1983 second crop.

Yield test	Blast resistance	BPH[a] resistance				BLB[b] resist.
		Bph 1	bph 2	BPh 3	bph 4	
Advanced	28	1	2	2	1	2
Preliminary	58	7	9	3	3	3
Donor parents	Tetep, Dawn TN6, M1-48 Carreon Dawn, Dular Shenso TNG62, BL2, 4, 5 Pil	TKM 6 IR 2178 CNGY 243 IR 28 IR 8073 IR 13415 IR 5533 CNGY 252	TNGS 12 TCS 10	TNGY 8005, 8849, Rathu- Heenathi	Babawee	Waseaikoku Other *Keng* var.

Yield test	Yellow dwarf resist.	Good rice quality	Aromatic rice	Semidwarf	Others	Total
Advanced	2	7	2	7	2	56
Preliminary	2	18	7	9	8	127
Donor Parents	Firooz	Hokuriku 100 Mutsunishiki Fujihikari Sasaminori Toyonishiki Ariake	Basmati	Chaoyanchao Milyang 23 TCS 3 Kwanluai	TPCZ Chyutze Silwah LM 182	43

a: Brown planthoppers. *b*: Bacterial leaf blast.

Resistance to white-backed planthoppers

The white-backed planthopper (WBPH), once a serious insect pest in Taiwan, easily becomes predominant when the host plant is resistant to BPH but not to WBPH. IRRI (18) reported four WBPH resistance genes in rice, i. e. *Wbph 1* from N22, *Wbph* 2 from Chempa, *Wbph 3* from ADR52 and *Wbph 4* from Podiwi-A8. Differences in the resistance existed among varieties identified as having the same major gene *Wbph 1* or *Wbph 2* (18) assuming to be due to minor gene differences. All the resistance soruces

explored by IRRI belong to *indica*. We tested a number of *japonica* varieties and strains for WBPH resistance cooperated with Applied Zoology Department, TARI. Tainung yuh 8849 and Chianung yuh 251 were found resistant, while Tainung 67 and Taichung 184 were moderately resistant. A genetic study revealed that the WBPH resistance of Tainung 67 seemed to be controlled by a single recessive gene. An expanded genetic study and breeding for WBPH resistance are in progress.

4. Application of anther culture to varietal improvement of japonica rice

In the past

The technique of anther culture in rice has been available for about a decade in Taiwan (6), yet, its impact on rice improvement has been very much limited. Rice breeders were not familiar with, or to some extent skeptical to the feasibility of, this technique to be used in rice breeding. In addition, it takes time to improve the culture technique particularly the medium (10) and to demonstrate that the anther-derived plants were of microspore origin. Chen *et al.* (8, 9) obtained the anther-derived plants of either *n* or *2n*, whose marker genes assorted in an independent manner or showed a linkage relationship. The results of genic analysis on the F_2 populations showed a good agreement with those from anther-derived plants (8). The conclusion that anther-derived plants are indeed of microspore origin is supported not only by the results of genetic studies but also by the cytological observation (8). In the past 15 years, public investments on rice breeding were centered mostly on the improvement of *indica* varieties or *indica-japonica* hybrids, even though the cultivated area of this rice has been dropping at an annual rate of about 10,000 ha. Since the percentage of callus formation by *indica's* anthers is very low, it is quite disadvantageous to apply this technique to *indica* rice breeding. On the other hand, most of desirable traits such as disease and insect resistances exist in the *indica*. We have to transfer these desirable traits by backcross breeding into Ponlai rice, that presently occupies more than 90% of the total rice area in Taiwan. As reported in the previous sections, the writer has been working on this direction to transfer various desirable traits into Tainung 67. Furthermore, anther culture was used in cooperation with the tissue culture laboratory, TARI for combining these traits in the Ponlai. The preliminary results obtained in this research work are shown below.

Anther culture of the double cross F_1's

In the 1982 second rice season, the hybrid materials in our backcross breeding program for BL resistance reached the BC_4 generation. The resistant BC_4 plants selected at Kuohsin BL nursery were brought back to the institute for double-crossing. As shown in Table 11, we selected 21 crosses of them for anther culture. Since the double cross F_1's may segregate for BL resistance, we subjected these hybrids F_1 No. 1462-1511 to blast test. Department of Plant Pathology, TARI inoculated them with the spore suspension of composite blast fungus. The susceptible F_1 plants were discarded by us to leave only the resistant plants for anther culture or continuous propagation and selection. According to the data obtained by the tissue culture laboratory, a total of 63,251 anthers from the F_1's of 21 crosses were cultured. The percentages of callus-

formed anthers ranged from 69.2% to 2.8% with an average of 30.5%. The total number of calluses that produced green plants was 1,596 (Table 11). In other words, only 8.1% of the calluses produced green plants, or 2.5% of the cultured anthers produced green plants. These percentages are considered low. Therefore, efforts are

Table 11. The AC_1 plants and AC_1S_1 lines of rice derived from anther culture of the double cross F_1's (1983 first and second crops).

F_1 NO.	Cross	AC_1 plants from test-tube	AC_1 plants in field				AC_1S_1 lines	
			Total	*n*	2*n*	Others	Grown	Select.
1462	TNG67[5]/Dawn//TNG67[5]/Carreon	10	3	2	1	0	1	1
1463	TNG67[5]/Dawn//TNG67[5]/Tetep	75	34	17	17	0	16	3
1472	TNG67[5]/Tetep//TNG67[4]/Dular	35	12	11	1	0	2	0
1473	TNG67[5]/Tetep//TNG67[5]/Carreon	133	48	23	25	0	24	9
1474	TNG67[5]/Tetep//TNG67[5]/Dawn	25	7	2	5	0	5	1
1478	TNG67[4]/Dular//TNG67[5]/Carreon	45	7	6	1	0	1	0
1481	F_2(TNG67[4]/Dawn)//F_2(TNG67[4]/Tetep)	99	30	25	5	0	5	2
1484	F_2(TNG67[3]/Dular)//F_2(TNG67[3]/Dawn)	118	28	18	10	0	9	1
1486	F_2(TNG67[4]/Tetep)//TNG67[4]/Dawn	331	187	126	56	5	59	14
1492	TNGY6043[b]//TNG67[5]/Tetep	5	1	1	0	0	0	0
1499	TNGY8023//TNG67[5]/Tetep	39	8	5	2	1	3	1
1501	TNGY8023//TNG67[4]/Tetep	26	6	1	5	0	4	1
1504	TNGY8814//F_2(TNG67[4]/Tetep)	0	0	0	0	0	0	0
1505	TNGY8814//F_2(TNG67[4]/Dular)	15	9	6	2	1	2	0
1507	TNGY8849//F_2(TNG67[4]/Dawn)	99	20	15	5	0	7	2
1508	TNGY8849//F_2(TNG67[4]/Dular)	66	25	16	9	0	9	5
1509	TNGY8933//TNG67[5]/Tetep	40	14	9	5	0	5	1
1511	TNGY8933//F_2(TNG67[4]/Dawn)	95	27	12	14	1	15	4
JF_1—15	TNGY6043/CNY252[a]	12	2	1	1	0	1	0
JF_1—16	TNGY8005/CNY252	0	0	0	0	0	0	0
JF_1—17	TNGY8023/CNY252	0	0	0	0	0	0	0
JF_1—18	TNGY8814/CNY252	78	30	22	8	0	11	2
JF_1—19	TNGY8849/CNY252	0	0	0	0	0	0	0
JF_1—20	TNGY8933/CNY252	116	48	17	29	2	34	7
JF_1—21	TNGY9198/CNY252	105	35	18	17	0	17	7
Total		1,567	581	353	218	10	230	61

a: Having *Bph 1*, blast and bacterial leaf blight resistances.
b: TNGY6043-9198, having *Bph 3* or other unidentified gene and blast resistance.

being made to improve these percentages by the tissue culture laboratory.

Among 1,567 green plants that were transferred from test-tubes to soil in pot, only 581 plants, or 37.1% survived in the paddy field (Table 11). The loss of green plants occurred at the stage immediately after the transfer of seedlings from test-tubes to soil. This percentage was greatly improved later by shortening the time period of seedlings in test-tubes or to transplant the young seedlings to sterilized soil and by giving the seedlings enough temperature and air moisture after the transfer. The breeder started to take care of these new plants that were finally transplanted to the paddy field. A bunch of seedlings from a cullus constitutes a hill in the field. Among 581 AC_1 plants, 353 or 60.8% showed a morphological feature characteristic of haploid, 218 or 37.5% were normal diploid and 10 or 1.7% were tetraploid or others(Table 11). We selected mostlly the diploid plants, that exhibited uniform characteristics within plants. A few plants had tillers showing distinctly different traits such as plant height or grain shape, indicating that different genotypes existed within plants althongh in a very low frequency. Panicle selection was practiced on this type of plants, if they looked desirable.

Serious panicle blast happened to occur on these AC_1 plants in the 1983 first crop, particularly on the susceptible haploid plants. All panicles of such haploid plants developed typical but serious blasting that had never been observed in the ordinary diploid plants. It seems that the haploid plants having only one set of chromosomes are particularly apt to diseases and insects, if they are susceptible. We may double the chromosome number at the adult stage of AC_1 plants or at the callus stage by colchicine treatment. The percentage of diploid plants may be raised by treating the calluses with a certain concentration of colchicine that acts most on haploid but less on diploid cells. For the present, we have to double the chromosomes at seedling stage after the seedlings are identified to be haploid. It was rather easy to identify the haploid seedlings by observing the sizes of epidermal cells including stomatal cells of leaves with SUMP or printing method. However, to treat the growing points of a large number of seedlings with colchicine is not an easy task. We moved about 20 haploid plants that were resistant to panicle blast into green house for ratoon culture. So far no any seed has been obtained from these stubbles. Therefore, the only way we can do with these AC_1 plants at present is to select normal and desirable plants, all being diploid, and to discard haploid, tetraploid and other undesirable plants.

Testing and selection of the AC_1S_1 lines

A total of 230 plants or panicles were selected from the AC_1's of the 21 crosses for progeny-testing (Table 11). The progenies of these plants will be thus AC_1S_1. We planted each of these AC_1S_1 lines in a paddy field for observing their performances and also tested for their resistances to the blast, bacterial leaf blight, brown planthopper and white-backed planthopper. As usual, upland BL nursery with corn border lines was used for BL test, and No. 604 strain of BLB bacterium was inoculated by us with clipping method for BLB test. Chiayi AES and Department of Applied Zoology, TARI respectively tested for BPH and WBPH resistances.

In general, these AC_1S_1 lines showed an acceptable degree of uniformity except a small number of lines. Those lines related with TNGY and CNY parents (Table 11) were mostly poor in plant-type, although many of them were resistant to both BL and BPH. Severe planthoppers including BPH and WBPH that frequently attacked the second rice crop brought down the yield per unit area of these lines. The yield of a line was estimated from 45 single-spaced plants. Their yields varied from 2 t/ha to 5.5 t/ha with 5 t/ha of the contol's yield. We bulked seed of 5 or 6 plants fom each of the selected lines to establish a strain for a preliminary yield test, and finally 61 strains were selected (Table 11).

Segregations of leaf blast resistance and nonshattering habit of grains among the AC_1S_1 lines.

The segregation of leaf blast resistance among the AC_1S_1 lines obtained from the F_1's of 7 crosses is shown in Table 12. Although the number of lines per cross in some crosses was small, the segregation of BL resistance apparently occurred among the AC_1S_1 lines derived from the F_1's between resistant parents. In some crosses, the segregation pattern could be explained based on the assumption of 3 or 4 pairs of genes that the parents differed (Table 12). Hence, there will be no problem to accumulate the resistance genes from different sources as we intent. However, how to identify the

Table 12. Segregation of leaf blast resistance among the AC_1S_1 diploid lines of rice derived from anther culture (upland BL nursery with corn border lines, 1983 second crop).

F_1 No.	Cross	1[a]	2	3	4	5	6	7	8	9	Total lines	Possible ratio $p(X^2)>5\%$
JF_1—18	TNGY8814/CNY252	7				2					9	1 : 1, 3 : 1
JF_1—20	TNGY8933/CNY252	21				4		1			26	3 : 1, 7 : 1
JF_1—21	TNGY9198/CNY252	9		5				1			15	7 : 1,15 : 1,31 : 1
F_1 1508	TNGY8849//F_2 (TNG67[4]/Dular)	8		1							9	?
F_1 1511	TNGY8933//F_2 (TNG67[4]/Dawn)	10								3	13	1 : 1, 3 : 1 7 : 1, 15 : 1
F_1 1486	F_2(TNG67[4]/Tetep)//TNG67[4]/Dawn	43		5		3		2		2	55	7 : 1
F_1 1473	TNG67[5]/Tetep//TNG67[5]/Carreon	9		2				4			15	1 : 1,3 : 1,7 : 1

a: BL disease degree, 1=highly resistant.

Table 13. Segregation of nonshattering (NS) and shattering (S) habits of grains among the AC_1S_1 diploid lines of rice derived from anther culture.

F_1 No.	Cross	NS	S	Total lines	$(1:1)\chi^2$
JF_1—18	TNGY8814/CNY252[a]	6	3	9	1.0^{ns}
JF_1—20	TNGY8933/CNY252	17	9	26	2.46^{ns}
JF_1—21	TNGY9198/CNY252	5	12	17	2.88^{ns}

a: Possessing nonshattering habit of grains.

Table 14. Segregation of brown planthopper resistance among the AC_1S_1 diploid lines of rice derived from anther culture.

F_1 No.	Cross	0.75*a*	2.25	3.75	5.25	6.75	8.25	Total lines	Possible ratio $p(X^2) > 5\%$
JF_1—18	TNGY8814/CNY252	3	1		1	1	3	9	1 : 1
JF_1—20	TNGY8933/CNY252	5	3	4	1		14	27	1 : 1
JF_1—21	TNGY9198/CNY252	7	1	3	1		3	15	1 : 1, 3 : 1
F_1 1508	TNGY8849//F_2 (TNG67[4]/Dular)	4					5	9	1 : 1
F_1 1511	TNGY8933//F_2 (TNG67[4]/Dawn)	3			1	4	6	14	

a: Average of BPH damage degrees, 1=highly resistant.

Table 15. Segregation of white-backed planthopper resistance among the AC_1S_1 diploid lines of rice derived from anther culture.

F_1 No.	Cross	R	S	Total lines
1486	F_2(TNG67[4]/Tetep)//TNG67[4]/Dawn	1	57	58
1505	TNGY8814//TNG67[4]/Dular	1	1	2
1508	TNGY8849//F_2 (TNG67[4]/Dular)	4	5	9
1511	TNGY8933//F_2 (TNG67[4]/Dawn)	3	11	14

genotype possessing a large number of resistance genes will be the next job for us to do. The genotypes having one and three or more resistance genes will show the same degree of resistance to a given range of pathogen. IRRI has been subjecting their rice materials to a wide range of blast fungus in the IRBN in order to identify the genotypes having a wide range of resistance. We may expand our range of BL nurseries to IRRI, Philippines or Japan for this purpose, although this range is still considered narrow. Or, we may test-cross the resistant AC_1S_1 lines to Tainung 67 and examine the segregation pattern of the test-cross F_2.

One parent, CNY252, happened to have the nonshattering habit of grains that could be used as the gene marker. In the crosses related with CNY252, the shattering and nonshattering lines of AC_1S_1 segregated in a ratio of 1:1 (Table 13). The shattering gene, *sh*, is located on the Takahashi and Kinoshita's linkage group 8 with many BL-resistance genes such as *Pi-a*, *Pi-5*, *Pi-k*, *Pi-m*, *Pi-4*, and *Pi-7* (23). A very close linkage is noted between *sh* and *Pi-a* genes (23). The ratio of shattering to nonshattering AC_1S_1 lines in the BL-resistance category deviated greatly from 1:1 probably due to the linkage between the two traits except in the cross of JF_1-18. JF_1-18 apparently did not have enough number of AC_1S_1 lines (Table 13). Since the nonshattering habit of grains is not desirable in Taiwan, it is better to avoid using CNY252 as the source of BL resistance.

Segregation of BPH and WBPH resistances among the AC_1S_1 lines

Table 14 shows the segreghtion patterns of BPH resistance in the AC_1S_1's of 5 crosses. The results seemed to deviate from what we had in mind. TNGY and CNY strains, both resistant to BPH, are supposed to possess different *Bph 3* and *Bph 1* genes, respectively; and the two genes are independent one another. The segregation patterns in Table 14 show as they possess the same resistance gene except JF_1-21 and F_1 1511. We still do'nt know the reason why the results did not come out as we expected.

Segregations of WBPH in the AC_1S_1's of 4 crosses are shown in Table 15. Among those parents used in crossing, only TNGY8849 is resistant to WBPH. The AC_1S_1 lines of F_1 1508 that was related with TNGY 8849 segregated for the WBPH susceptible and resistant in a ratio of 1:1 (Table 15). A very low frequency of resistant lines that appeared in other crosses probably had their origin of resistance from Tainung 67. Even though Tainung 67 was rated moderately resistant to WBPH in our early test, many AC_1S_1 lines that received 4 doses of Tainung 67 did not show any resistance (Table 15). There apparently remain still many questions to be answered about the BPH and WBPH resistances in these anther-derived AC_1S_1 lines.

Acknowledgements

The author is grateful to Mr. R. H. Buu for assisting the breeding work, to Dr. C. H. Cheng for testing the insect resistance and to Dr. H. S. Tsay for conducting the anther culture.

References

1. Anonymous. 1983. R/J interview: The sad shape of rice and more's coming. Rice J. Ann. Issue, 1983 : 6-7, 10-13.
2. Anonymous. 1983. Taiwan: U. S. claims the dumping's underway. Rice J. Ann. Issue, 1983 : 8-9.
3. Buu, R. H. and C. S. Huang. 1983. Studies on the improvement of blast disease resistance of *japonica* rice, Tainung 67. J. Agrl. Res. China 32(2)201-208 (in Chinese with English summary).
4. Chang T. T., M. K. Wang, K. M. Lin and C. P. Cheng. 1963. Breeding for blast resistance in Taiwan. The Rice Blast Disease, IRRI, Philippines. pp. 371-377.
5. Chang, W. L. 1982. Tainung 68, the first BPH-resistant *japonica* cultivar developed in Taiwan. International Rice Research Newsletter 7(4) : 8.
6. Chen, C. C. 1974. Anther culture of rice and its related species. Annual Report for 1973, Taiwan Agrl. Res. Inst. pp. 44-45 (in Chinese).
7. Chen, C. C., H. H. Ho, W. H. Ko and C. C. Chang. 1972. Screening tests for resistance to yellow dwarf in rice. Bull. Taichung District Agrl. Impr. Stat. No. 2 (in Chinese with English summary).
8. Chen, C. C., W. L. Chiu, L. J. Yu, S. S. Ren and W. J. Yu. 1983. Genetic analysis of anther-derived plants of rice: independent assortment of unlinked genes. Can. J. Genet. Cytol. 25 : 324-328.
9. Chen, C. M., C. C. Chen and M. H. Lin. 1982. Genetic analysis of anther-derived plants of rice, J. Hered. 73 : 49-52.

10. Chen, L. J., P. C. Lai, C. H. Liao and H. S. Tsay. 1982. Medium evaluation for rice anther culture. J. Agrl. Res. China 31(4) : 283-290 (in Chinese with English summary).
11. Chen, L. C. 1981. Pedigrees of the blast resistant *japonica* cultivars in Taiwan. Symp. on Rice Breeding for Blast Resistance, Institute of Botany/Academia Sinica, Taipei (in Chinese, in press).
12. Cheng, C. H. and W. L. Chang. 1979. Studies on varietal resistance to the brown planthopper in Taiwan. Brnown planthopper: Threat to Rice Production in Asia, IRRI, 251-271.
13. Chiu, S. M. and Y. C. Teng. 1975. Yield and resistance of rice blast resistant composite varieties. J. Agrl. Res. China 24(1.2) : 1-10 (in Chinese with English summary).
14. Huang, C. S. 1979. A break through in the ceiling grain yield of ponlai rice, International Rice Research Newsletter 4(6) : 4.
15. Huang, C. S. 1981. Rice breeding for blast disease resistance in the past 20 years at Taiwan Agricultural Research Institute. Symp. on Rice Breeding for Blast Resistance, Institute of Botany, Academia Sinica, Taipei (in Chinese, in press).
16. Huang, C. S., Buu, R. H., C. Cheng and C. Liu. 1982. Breeding for resistance to brown planthopper in *Keng* (*japonica*) rice. Proc. Pl. Breed. Symp. sponsored by ROC Regional Society of SABRAO and Agrl. Assoc. China. pp. 89-97.
17. Hsieh, S. C., M. H. Lin and H. L. Liong. 1967. Genetic analysis in rice VIII, Inheritance of resistance to races 4, 22 and 25 of *Piricularia oryzae* Cav. Bot. Bull. Academia Sinica 8 : 255-260.
18. IRRI Annual Report for 1980 : 58-59, and for 1981 : 59-63. International Rice Research Institute, Philippines.
19. Kinoshita, T. 1982. Linkage groups and linkage map of rice. In "Present Status of Gene Analysis in Rice" ed. by T. Omura, Univ. of Kyushu pp. 11-28 (in Japanese).
20. Liao, Y. M. and C. C. Chen, 1982. Pathotypes of *Xanthomonas campestris* pv. *oryze* in Taiwan. J. Agril. Res. China 34(4) : 321-333 (in Chinese with English summary).
21. Lin, M. H., C. L. Chu and C. C. Chien. 1975. Inheritance of resistance to yellow dwarf disease of rice. J. Agrl. Res. China. 24(1.2) : 1-7 (in Chinese with English summary).
22. Lin, M. H., T. M. Chang, C. C. Chien and Y. C. Chang. 1980. Breeding for the resistance to yellow dwarf disease of rice. J. Agrl. Res. China 29(4) : 259-264(in Chinese with English summary).
23. Omura, T. 1982. Present Status of Gene Analysis in Rice. Research Group of Rice Gene. Univ. of Kyushu (in Japanese).
24. Ou, S. H. and others. 1982. Report of cordination subcommittee of plant protection research, Science Advisory Committee, Executive Yuan. Committee of Agrl. Planning and Development (inChinese).
25. Ou. S. H. 1983. Studies on rice blast: Cytology of the fungus and resistance breeding. General Report to National Science Council, ROC (NSC71-0409-B055-03). TARI (Mimeographed, in Chinese).
26. Pathak, M. D. and G. S. Khush. 1979. Studies of varietal resistance in rice to the brown planthopper at the International Rice Research Institute. In Brown Planthopper: Threat to Rice Produ ction in Asia, IRRI, pp. 285-301.
27. Wu, H. K., C. L. Chen and J. P. Wang, 1979. Races of *Pyricularia rryzae* Cav. and rice cultivar resistance. Natl. Sci. Counc. Monthly, ROC, 7(5) : 497-516(in Chinese with English summary).
28. Yokoo, M., F. Kikuchi, H. Fujimaki and K. Nagai 1978. Breeding of blast resistant lines (BL 1 to 7) from *indica*-japonica crosses of rice. Jap. J. Breed. 28(4) : 359-385 (in Japanese with English summary).

粳稻抗病蟲育種[1]

黃眞生[2]

摘要

爲改良臺農67號之稻熱病抵抗性，將臺農67號 Tetep, Carreon, Dawn 等捐與品種雜交，然後回交於臺農67號3至4次。其 BC_1F_1 之遺傳研究顯示，對四個稻熱病病菌生理小種， Tetep 是最富有抗病基因之種源。另創設玉米保護行稻熱病病圃，以便迅速篩選育種系統。由此育種計畫選得多數品系，均具有稻熱病抵抗性，且比臺農67號高產。我們同時將臺農67號與抗黃萎病的 Firooz 雜交，後回交臺農67號2次。由回交分離後代選出11品系乃抗黃萎病者，其中有二品系比臺農67號高產。經過2次的育種計畫，將野生稻 *Oryza rufipogon* 褐飛蝨抵抗性轉移至蓬萊稻，最後選出抗稻飛蝨及稻熱病的 TNGY 8849 將提出命名登記。臺農 67 號也同樣與具 *Bph 1, bph 2, Bph 3* 及 *bph 4* 的種源雜交，後回交臺農67號2次。由此選出之品系正在參試於產量比較試驗。另經測驗明瞭有數個粳稻品種對白背飛蝨有抵抗性，有關此蟲抵抗性的遺傳育種試驗正在進行中。另與組織培養室合作，做21個雙交 F_1 之花藥培養，是上述回交育種育成系統或品系間的雙交。從 1,567 個綠色的 AC_1 營養系，得到 230 雙倍體 AC_1S_1 系統以供篩選之用。此雙倍體之出現比率後來得大幅提高。由稻熱病，稻飛蝨抵抗性以及脫粒性等在 AC_1S_1 之分離形式而言，雙交及花藥培養的運用使不同優良性狀合併於同一品種應該是可行而能迅速完成。

1.臺灣農業試驗所 研究報告第 1239 號。
2.本所農藝系研究員。臺灣省 臺中縣 霧峰鄉。